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The role of the iliofemoral ligament as a stabilizer of the hip joint

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■ The purpose of this systematic literature review is to analyse the role of the iliofemoral ligament (ILFL) as a hip joint stabilizer in the current literature.

■ A total of 26 articles were included in the review. The ILFL is the largest hip ligament consisting of two distinct arms and is highly variable, both in its location and overall size, and plays a primary role in hip stability; in the case of hip dislocation, the iliofemoral ligament tear does not heal, resulting in a persistent anterior capsule defect. Clinically, the ILFL is felt to limit external rotation in flexion and both internal and external rotation in extension.

■ The abduction–hyperextension–external rotation (AB-HEER) test is overall the most accurate test to detect ILFL lesions. Injuries of the ILFL could be iatrogenic or a consequence of traumatic hip instability, and can be accurately studied with magnetic resonance imaging. Different arthroscopic and open techniques have been described in order to preserve the ILFL during surgery and, in case of lesions, several procedures with good to excellent results have been reported in the existing literature.

■ The current systematic review, focusing only on the ILFL of the hip, summarizes the existing knowledge on anatomy, imaging and function and contributes to the further understanding of the ILFL, confirming its key role in anterior hip stability. Future studies will have to develop clinical tests to evaluate the functionality and stability of the ILFL.

Keywords: biomechanics; hip capsule; hip joints; iliofemoral ligament; stabilizer

Introduction

The capsule of the hip joint is a cylindrical-shaped arrangement of dense fibres connecting the acetabulum and femur through firm proximal attachments to the acetabular periosteum and distal attachments to the inter-trochanteric line on the femur anteriorly.[1] The thickness of the capsule has been observed to vary, but it is reinforced consistently by the capsular ligaments. These ligaments guarantee stability and prevent the hypermobility of the hip.[2] They provide a slack region in which the femur can rotate freely but pull taut, either individually or collaboratively, to restrict hypermobility. The primary region of joint laxity for internal rotation (IR) or external rotation (ER) and abduction or adduction occurs in mid-flexion. Thus, during normal activities performed in mid-flexion, the hip can move freely under muscle action, without being limited by the ligaments.[3] However, at full flexion or extension or full abduction or adduction, the slack region is minimal. The capsular ligaments thus allow for a full range of movement where the ball-in-socket morphology provides all the requisite stability to the joint but limits the available range of rotation in positions in which the hip is vulnerable to impingement, edge loading or subluxation.[4] The iliofemoral ligament (ILFL) is the strongest and most important hip capsular ligament, located anteriorly and originating from just below the anterior inferior iliac spine (AIIS). It consists of two limbs: the medial limb is vertically oriented, while the lateral arm is oriented more obliquely. The ILFL plays a key role in acting as a primary restraint against excessive ER.[5]

The present review aims to analyse current knowledge by focusing on contemporary data and available studies about anatomy, imaging, clinical testing, function and iatrogenic injury during surgery regarding the ILFL, accompanied by arthroscopic and magnetic resonance images taken from the authors' record. This is prompted by the fact that, in current literature, there are numerous papers that analyse the ILFL, but always in association with other capsulo-ligamentous structures.
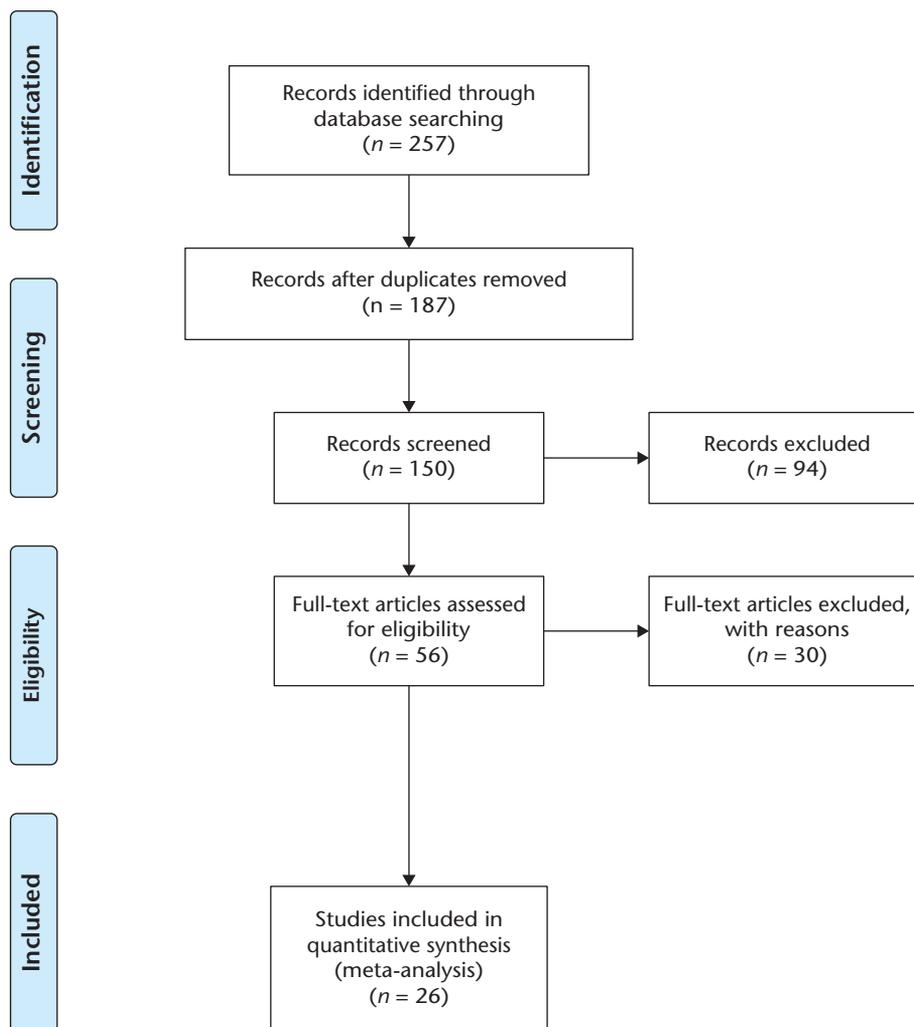
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Records identified through
database searching
(n = 257)
            │
            ▼
Records after duplicates removed
(n = 187)
            │
            ▼
Records screened          ──────▶   Records excluded
(n = 150)                            (n = 94)
            │
            ▼
Full-text articles assessed ─────▶  Full-text articles excluded,
for eligibility                     with reasons
(n = 56)                            (n = 30)
            │
            ▼
Studies included in
quantitative synthesis
(meta-analysis)
(n = 26)
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Fig. 1 A flowchart of the literature screening performed in this study.

Methods

A systematic review of the existing literature was performed to identify all the studies dealing with anatomy, biomechanics, imaging and surgery involving the ILFL. The guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) were followed for the identification of the articles.[6]

The literature search was performed by two independent investigators using MEDLINE, Scopus, Embase, CINAHL and Cochrane Databases. For the search, the following terms were used: "Iliofemoral ligament" OR "ILFL" OR "IFL" OR "hip ligaments" OR "hip capsule" AND "biomechanics" OR "histology" OR "microscopic" OR "cadaveric study" OR "anatomy" OR "imaging" OR "clinical test" OR "physical examination" OR "surgery" OR "hip arthroscopy" OR "hip arthroplasty". The search also included the references of all the articles identified and the references of the systematic review. After the first screening, 257 articles were identified, of which 201 were excluded and, of the remaining 56, 26 articles were in line with the inclusion criteria that were selected (Fig. 1).

Eligibility and exclusion criteria

In this systematic review, studies of level I, II, III, IV and case reports were included. The assessment of the level of evidence of the selected article was performed according to 'The Oxford 2011 Levels of Evidence'.[7] Animal studies and reviews, meta-analyses and editorials were excluded. Two independent reviewers analysed and evaluated all the information in the articles. In the case of disagreement between the two reviewers, a third senior reviewer was asked to evaluate and analyse the disputed article. Information regarding the author, data and journal of publication, study design and level of evidence were extracted and entered into a spreadsheet for analysis. The articles were then divided into five categories

(anatomy, imaging, clinical test, function and the role of the ILFL during surgery).

Results

Anatomy

In 2014, Telleira et al described the hip joint capsule and ligaments quantitatively using a three-dimensional digitizing system and computer modelling.[8] The area and dimensions of the three main hip capsular ligaments (ILFL, pubofemoral ligament [PFL] and ischiofemoral ligament [ISFL]) and their insertional footprints were quantified in eight cadaveric hips.

The ILFL resulted in an inverted 'Y'-shaped footprint and was distally split into two distinct arms, the medial (MILFL) and lateral ILFL (LILFL). The single proximal insertion abutted the AIIS, wrapping around the base like a crescent and extending to within a few millimetres of the acetabular rim along the anterior and anterolateral acetabulum. Distally, the LILFL crossed the joint obliquely and was inserted into the anterior prominence of the greater trochanteric crest, just superior to the origin of the inter-trochanteric line, with an elongated oval-shaped footprint. The MILFL coursed almost vertically inferior and was inserted into a subtle angulated prominence of the anterior–inferior femur, at the level of the lesser trochanter, with a circular footprint. The individual arms of the ILFL diverged by 57 mm (in a range of 50–64 mm) distal to the most superior aspect of the proximal attachment footprint; the medial and lateral insertional footprints were a few millimetres apart on the inter-trochanteric line. The distal lateral ILFL and distal ISFL insertional footprints were separated by a small gap of capsular tissue and did not blend into each other. The fibres of the PFL blended anteriorly with the medial arm of the ILFL.[8] Detailed areas and distances are reported in Tables 1 and 2.

In 2011, Nam et al used computer navigation to explore the specific origins of the hips' capsulo-ligamentous
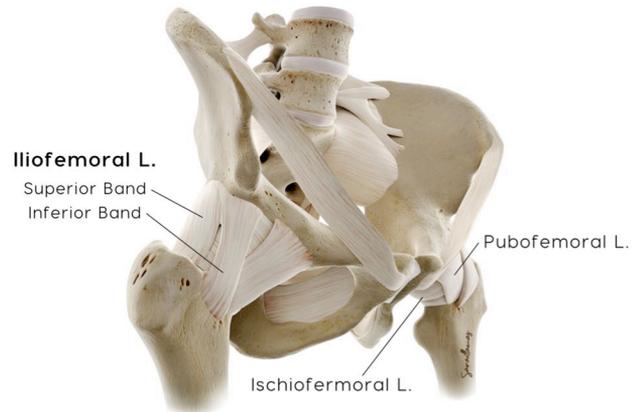
Table 1. Quantitative relationships of iliofemoral ligament attachment footprints as reported by Telleria et al.[8]

Relationship	Mean distance (mm)
Proximal FT to ASIS apex	53
Proximal FT to AIIS apex	13
Proximal FT to acetabular rim	3
Proximal FT to ILFL arm divergence	57
Distal lateral FT to distal medial FT	2
Distal lateral FT to ISFL distal FT	7
Distal lateral FT to ILFL arm divergence	20
Distal lateral FT width at divergence	25
Distal medial FT to lesser trochanter apex	20
Distal medial FT to ILFL arm divergence	27
Distal medial FT width at divergence	22

Note. FT, footprint ; ASIS, anterior superior iliac spine ; AIIS, anterior inferior iliac spine; ILFL, iliofemoral ligament; ISFL, ischiofemoral ligament.

Table 2. Iliofemoral ligament insertional footprint area as reported by Telleria et al.[8]

Attachment footprint	Mean length (mm)	Mean width (mm)	Mean area (cm²)
ILFL proximal	15	27	4.2
ILFL distal medial	31	20	4.8
ILFL distal lateral	38	11	3.1

Note. ILFL, iliofemoral ligament.
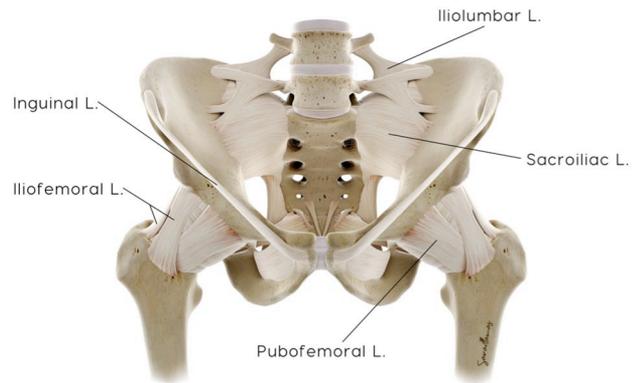
Fig. 2 Anteroposterior view of the hip showing ligamentous structures.

Fig. 3 Lateral view of the hip showing capsular hip ligaments.

complex, utilizing six fresh frozen cadaver hips.[9] As with landmarking of the AIIS, the mean midpoint of the origin of the ILFL is located at the 1:26 position, the ligament originates at 12:35 and extends to 2:18. In degrees, the ligament originates at 17° from the 12 o'clock position, and ends at 69°, spanning a mean distance of 52° around the acetabular clockface. The ILFL presented the greatest variability with regard to the starting and end points of its origin and overall size when compared to the ISFL and PFL.[9] A detailed anatomy of the ILFL is reported in Fig. 2 and Fig. 3.

Arthroscopic anatomy

Telleira et al described the normal arthroscopic intra-articular anatomy of the hip capsular ligaments in the central and peripheral compartments of the hip joint.[10] The divergence of the ILFL medial and lateral arms occurred distally to the joint line, and the individual arms could not be visualized arthroscopically. In the central compartment of the ILFL, the lateral border was lateral to the antero-lateral portal and the medial border was medial to the anterior portal; both portals pierced the ligament. In the peripheral compartment, the ILFL lateral border was anterior to the lateral synovial fold at the level of the head and neck junction and the medial border was lateral to the medial synovial fold at the level of the zona orbicularis.[10] An arthroscopic view of the ILFL is reported in Fig. 4.

Histology

A histologic study, published in 2012, showed that the microscopic direction of collagen fibres in the ILFL was parallel to the macroscopic direction, suggesting that this ligament may play a part in restricting the extension of the hip joint.[11] Thus, from the low density of the crimp distribution in the longitudinal plane, the ILFL may contribute to the stability of the hip joint in the standing position in the living body.[11]

In 2013, Lorda-Diez et al studied the relative expression levels of a subset of key genes of three different ligaments: the anterior cruciate ligament (ACL), ligamentum teres (LT) and ILFL.[12] The authors found significant differences in the expression of type I collagen, elastin, fibromodulin, biglycan, transforming growth factor beta-1, transforming growth interacting factor 1, hypoxia-inducible factor 1-alpha and transforming growth factor beta-induced gene between the ILFL and the other two ligaments, thus indicating that considerable molecular heterogeneity can exist between anatomically distinct ligaments with differing biomechanical demands.[12]
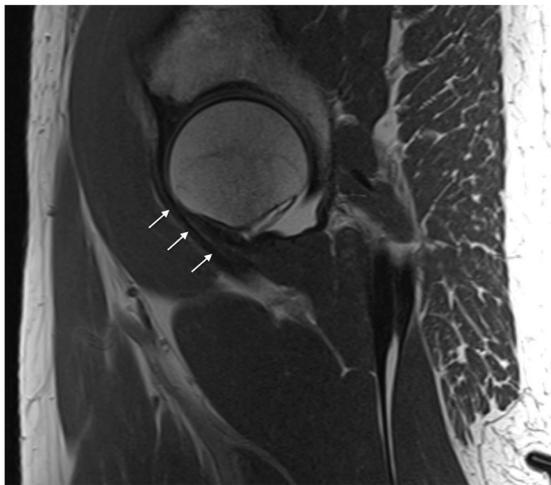
Imaging

Wagner et al analysed in detail the ILFL, through the use of MRI arthrographic images of 10 fresh human cadaveric hips.[13] Magnetic resonance imaging (MRI) was performed with a 1.5-T MR imager (Signa; GE Medical Systems, Milwaukee, WI, USA) with a transmit-receive birdcage-type head coil centred over the femoral head. Sequence parameters were as follows: 600/17; section thickness of 3 mm; two acquired signals; field of view of 13 cm; and matrix of 512×512. Two readers, working in consensus, graded the visibility of these structures and collected tissue samples for histologic analysis. The MRI showed the ILFL as a thick bundle of fibres reinforcing the anterior aspect of the capsule. It originated proximally from the lower part of the AIIS and the iliac portion of the acetabular margin. Superiorly, the ligament was strengthened by recurrent fibres which originated from the rectus femoris muscle. The ILFL had a fan-shaped arrangement of fibres, as it was inserted distally along the inter-trochanteric line, with thicker peripheral portions and a thinner central portion between them. In this thickening, it is possible to identify two distinct bands: the inferior band of the iliofemoral ligament (IBILFL) and the superior band of the iliofemoral ligament (SBILFL). The IBILFL passed in a downward, near-vertical direction to attach to the lower part of the inter-trochanteric line. The SBILFL presented a more horizontal orientation running laterally and downward, to attach to the upper part of the inter-trochanteric line and the base of the greater trochanter. The best visualization for the IBILFL was in the axial and axial-oblique planes transversely and in the sagittal plane longitudinally. For the SBILF, the best places are the coronal and axial-oblique. On the sagittal plane, it was possible to note the taut appearance of the IBILFL, and its longer length with the hip extension and a shorter length with the hip flexed, confirming its role in the restriction of extension. The SBILFL showed, in the axial plane, an elongation in ER and a shortening during IR, suggesting a role in the restriction of ER (Figure 5 and 6).[13]

Recently, Jia et al assessed the prevalence of the dislocation of the anterior hip and highlighted the distinctive imaging features of anterior-superior hip dislocation.[14] Follow-up MR arthrography conducted 11 months later showed that the superior capsule injury had healed, but the iliofemoral ligament defect remained. This defect creates the potential for anterior hip instability, as has been previously reported in patients who are left with iliofemoral ligament defects after arthroscopic surgery for femoroacetabular impingement.

Fig. 4 Extra-articular view from the anterolateral portal.
*Iliofemoral ligament.
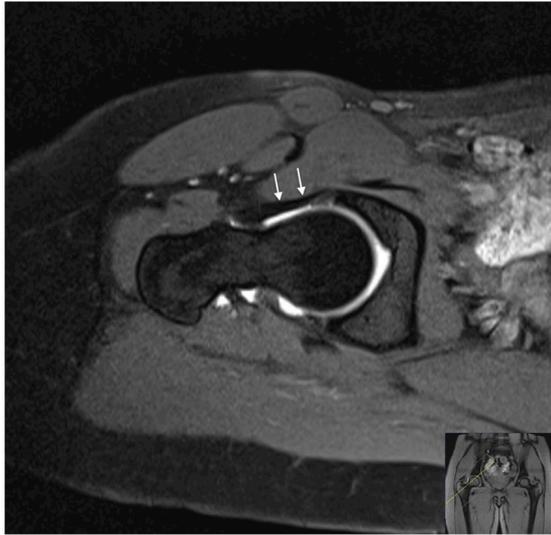
Fig. 5 MRI arthrography. Oblique axial T1-weighted fat-suppressed image showing the iliofemoral ligament (white arrows) as a thick band lying anteriorly to the capsule.

Note. MRI, magnetic resonance imaging.

Fig. 6 MRI arthrography. Oblique sagittal proton density image showing the iliofemoral ligament (white arrows) as a band lying anteriorly to the capsule.

Note. MRI, magnetic resonance imaging.

Clinical tests

The iliofemoral ligament is felt to limit ER in flexion and both IR and ER in extension. A study of intact ligaments found increased strain on the lateral arm with maximal ER in adduction and increased strain on the medial arm with ER in extension.[15] The positions to assess for ligament laxity have included hip extension and ER with and without abduction.[15] However, considering the orientation of the iliofemoral ligament fibres in relation to the hip joint axis, a position with extension, ER and adduction may be the best position to assess for iliofemoral ligament laxity.[15]

Hoppe et al determined the test characteristics and diagnostic accuracy of three physical examination manoeuvres in the detection of hip microinstability, including the abduction–hyperextension–external rotation (AB-HEER) test, the prone instability test and the hyperextension–external rotation (HEER) test (Table 3).[16] The AB-HEER test was overall the most accurate test, having the highest sensitivity (80.6%), negative predictive value (77.8%), overall accuracy (84.4%) and second-highest specificity (89.4%). The most specific test was the prone instability test (97.9%), which also had the highest positive predictive value (95.5%) but a very low sensitivity (33.9%). The HEER test performed second best in both sensitivity (71.0%) and overall accuracy (77.1%).[16]

Biomechanical characteristics

A total of 11 articles dealt with the ILFL biomechanics used on specimens. The summarized results are reported in Table 4. Schleifenbaum et al analysed the tensile properties of the hip ligaments in cadavers of a large age range.[17] For the ILFL, maximum strain was 84.5%, and ultimate stress was 10.0 N/mm². Martin et al noted that when the hip was in IR, and the MILFL was severed, no notable change was observed.[18] However, when the LILFL was cut, an increase of 5° was seen in all positions except the 30° flexion. The contribution of the LILFL increases as the femur moves from flexion to extension along a neutral swing path. The lateral arm was observed to have a greater contribution in all locations along the neutral swing path, except for extension.[18]

Van Arkel et al demonstrated that the ILFL provided primary ER restraint in all hip positions, and both primary IR

Table 3. Clinical test to detect ILFL injuries

Test	Position / Procedure	Sign
Prone instability	Prone; passive external rotation while the examiner applies an anteriorly directed force on the trochanter	Hip joint pain or sense of anterior instability
HEER/Anterior apprehension	Supine at the end of the table with affected leg hanging off and unaffected knee toward chest; passive hip extension and external rotation	Hip joint pain or sense of anterior instability
AB-HEER	Side lying on unaffected hip; passive hip abduction to 30°, extension 10° and external rotation to end range while an anteriorly directed force applied to trochanter	Hip joint pain or sense of anterior instability

Note. ILFL, iliofemoral ligament; AB-HEER, abduction–hyperextension–external rotation test; HEER, hyperextension–external rotation test.

Table 4. Specific data from biomechanics studies included in the review

Author	Journal	Type of article	Biomechanics evaluation	Number of specimens	ILFL biomechanics
Joint function					
Schleifenbaum et al 2016[17]	*Journal of Biomechanics*	Controlled laboratory study	Stress–strain data of ILFL, ISFL and PFL were obtained from cadavers using a highly standardized setting. Maximum strains were compared to the distances required for dislocation.	21 (40 hips; age 14–93 years)	The mean elastic modulus was 24.42±1.0 N/mm2 for the ILFL Maximum strain was 84.5±36.0% The elastic modulus was higher in the young group than in the old group (31.0±22.5 vs. 18.3±17.9 N/mm2) Ultimate stress was higher in the young than in the old (13.1 ±9.1% vs. 7.1±4.7%).
Pieroh et al 2016[2]	*PloS One*	Controlled laboratory study	Uniaxial stress–strain properties were obtained from the load-deformation curves before the secant elastic modulus was computed. Strain, elastic modulus and cross sections were compared.	17 (12 hips; 83.65 ± 10.54 years)	ILFL: Cross-sectional area of 53.5±15.mm2 Mean strain: 129.8±11.1% Elastic moduli: 48.8±21.4 N/mm2
Martin et al 2008[18]	*Arthroscopy*	Controlled laboratory study	The motion at the hip joint was measured in internal and external rotation through ranges of motion from 30° flexion to 10° extension along a neutral swing path. The motion was standardized by use of frame stabilization and motion tracking.	12 hips (mean 62 years)	The release of the MILFL and LILFL each gave the greatest increase of motion in external rotation, with the LILFL release providing more range of motion in flexion and in a neutral position. The LIFL release also showed a significant motion increase in internal rotation, primarily in extension.
van Arkel et al 2015[19]	*Bone Joint J*	Controlled laboratory study	The hip was rotated throughout a complete ROM and the contributions of the MILFL and LILFL, PFL and ISFL and the LT to rotational restraint was determined by resecting a ligament and measuring the reduced torque required to achieve the same angular position as before resection.	9 (18 hips; age 61–89 years)	The ILFL provided primary external rotation restraint in all hip positions, and both primary internal and external rotation restraint when the hip was extended or in neutral hip flexion. The MILFL dominated in neutral flexion or extension, and the lateral arm in all other positions.
Hidaka et al 2014[20]	*Clin Anatomy*	Controlled laboratory study	Clinically available stretching positions for ligaments were adopted. Strain on each ligament was measured by a displacement sensor during passive torque to the hip joint. Hip motion was measured using an electromagnetic tracking device. The strained ligaments were captured on clear photographs.	8 (age 81–98 years)	Strain (%) SBILFL: Extension: 0.30±0.53; Add 0.86±1.60; ER 3.48±2.57; Extension 10° + ER: 0.74±1.29; Add 10° + ER 2.58±3.53 IBILFL: Extension: 1.86±1.22; Add 0.0±0.0; ER 0.65±1.27; Er 10° + Ext: 1.46±0.85; ER 20° + Ext 1.25±0.63; ER 30° + Ext: 0.57±0.56
Hidaka et al 2009[21]	*Manual Therapy*	Controlled laboratory study	Strains on the SBILFL and IBILFL were measured using a displacement sensor, and the range of movement of the hip joints was recorded using a 3Space Magnetic Sensor. Reference length (L0) for each ligament was determined to measure strain on the ligaments.	8 hips (age 67–91 years)	Strain SBILFL: add 10° with maximal ER: 3.2±3.3%; Add 20° with maximal ER: 4.0±4.2%; maximal ER 3.7±3.0% IBILFL: maximal extension: 2.1±2.1%; maximal extension and 20° ER: 1.8±2.1%
Ito et al 2009[22]	*J Orthop Res*	Controlled laboratory study	Each specimen was tested at a neutral hip position of 0° flexion, 0° abduction, and 0° internal rotation. Tensile force was applied parallel to the longitudinal axis of the femoral shaft. After 10 cycles of preconditioning from 20 to 100 N at a distraction rate 0.4 mm/s, each specimen was loaded in tension by distracting the femur longitudinally from the acetabulum at a constant rate of 0.4 mm/s to a displacement of 5 mm. The applied tensile load and crosshead displacement were recorded at time intervals of 0.01 s.	7 (age 59–85 years)	With the distraction load in the normal condition defined as 100%, the load required to cause 3-mm joint displacement was reduced to 82% after incising the ILFL. The distraction load did not significantly decrease after the ILFL was incised compared to just venting the capsule.

(continued)

Table 4 (continued)

Author	Journal	Type of article	Biomechanics evaluation	Number of specimens	ILFL biomechanics
Bakshi et al 2017[24]	*Orthop J Sports Med*	Controlled laboratory study	5 different tests: intact capsule, intact labrum (all intact); sutured capsule, intact labrum (sutured intact); sutured capsule, 1-cm partial labrectomy (sutured labrectomy); partial capsulectomy, 1-cm partial labrectomy (partial capsulectomy); and total capsulectomy, 1-cm partial labrectomy (total capsulectomy). Each hip was tested in a neutral position with a 20-N compressive force. The load at 12 mm of anterior translation was recorded for each state after 2 preconditioning trials.	8 (16 hips; age 29–64 years)	ILFL plays a primary role in anterior hip stability in the labral-injured state providing a restraint to anterior translation when the stabilizing effect of the labrum has been lost.
Myers et al 2011[23]	*Am J Sports Med*	Controlled laboratory study	Each specimen was selectively skeletonized down to the hip capsule. Four tantalum beads were embedded into each femur and pelvis to accurately measure hip translations and rotations using biplane fluoroscopy while either a standardized 5 N_m external or internal rotation torque was applied. The hips were tested in 4 hip flexion angles (10° of extension, neutral, and 10° and 40° of flexion) in the intact state and then by sectioning and later repairing the acetabular labrum and ILFL in a randomized order.	8 (16 hips; age 53–68 years)	External rotation significantly increased by 12.9°±5.2° after sectioning of the iliofemoral ligament alone (54.4°±6.6°). External rotation significantly increased by 7.1°±5.9° from the ILFL-alone sectioned condition (54.4°±6.6°) to when both the labrum and ILFL were sectioned in the both-sectioned condition. When only the ILFL was repaired (42.5°±6.1°) compared with the both-sectioned condition (61.5°±5.7°), a significant decrease in external rotation of 19.0° was found sectioned ILFL alone resulting in significantly greater anterior translation of the femur.
Kivlan et al 2019[15]	*Int J Sports Phys Ther*	Exploratory cohort study with good reference standards	A string model representing the medial and lateral arms of the ILFL ligament was secured to the proximal and distal attachment points. The amount of length change of the string model was compared in four test positions: 1) external rotation, 2) hyperextension-external rotation 3) abduction-extension-external rotation, and 4) adduction-extension-external rotation.	9 (12 hips; age 57–84 years)	For the MILFL, the greatest change occurred in the adduction-extension-external rotation position (12.7 mm). This was significantly greater than the external rotation (5.1 mm; p = 0.002) and abduction-extension-external rotation position (1.9 mm; p < 0.001). The LILFL also had the greatest excursion in the adduction-extension-external rotation position (16.6 mm). This length change was significantly greater than the external rotation position (8.6 mm; p = 0.002), the hyperextension-external rotation (11.1 mm; p = 0.047), and the abduction-extension-external rotation position (5.6 mm; p < 0.001).
Burkhart et al 2020[25]	*Knee Surg Sports Traumatol Arthrosc*	Controlled laboratory study	Each specimen was tested at five passive hip flexion angles (15° of extension [−15°], 0°, 30°, 60°, and 90°). At each flexion angle, a baseline scan was taken where a 10 N axial load was applied with all other load axes set to 0 N and 0 Nm.	7 hips; age 78.3±6.0	SBILFL: There was a significant flexion angle by loading type interaction with respect to the SBILFL. The application of IR increased the relaxation of the ligament across all tested positions with significantly less strain in the ligament at 30° and 60° compared with 0°. The strains were significantly different between IR and ER at all flexion angles. IBILFL: There was a significant flexion angle by loading type interaction for the IBILFL; however, pairwise differences could not identify differences for either IR or ER. Qualitatively, however, the application of an IR reduced the strains in the IBILFL across all tested positions, while the application of an ER increased the strains in the IIFL across hip flexion angles. Strains were significantly different between IR and ER at all flexion angles.

Note. ILFL, iliofemoral ligament; LILFL, lateral arm of the iliofemoral ligament; MILFL, medial arm of the iliofemoral ligament; ISFL, ischiofemoral ligament; PFL, puboferamoral ligament; IBILFL, inferior band of the iliofemoral; SBILFL, superior band of the iliofemoral ligament; LT, ligamentum teres; ROM, range of motion; ER, external rotation; IR, internal rotation.

and ER restraint when the hip was extended or in a neutral hip flexion.[19] Hidaka et al noted that significantly high strains were imposed on the SBILFL by the ER of the hip (3.48%), on the inferior ILFL by maximal extension and by 10° or 20° of ER with maximal extension.[20] The same author, in a previous biomechanical study, demonstrated that superior and inferior iliofemoral ligaments exhibited positive strain values with specific stretching positions.[21]

Recently, Pieroh et al revealed no significant differences in ligaments with respect to gender-specific differences among the ILFL, ISFL and PFL. The ILFL (53.5 ± 15.1 mm^2) yielded a significantly higher cross-section as compared to the ISFL and PFL.[2]

Ito et al analysed the structure and function of the proximal hip joint capsule by performing tests in eight sequential conditions: (1) intact specimen (muscle and skin removed), (2) capsule vented, (3) incised ILFL, (4) circumferentially incised capsule, (5) partially resected capsule (distal to the zona orbicularis), (6) completely resected capsule, (7) radially incised labrum and (8) completely resected labrum.[22] With the distraction load in the normal condition defined as 100%, the load required to cause a 3-mm joint displacement was reduced to 82% after incising the ILFL, showing that the ILFL ligament did not contribute to hip stability in distraction up to 5 mm.[22]

Myers et al evaluated, using biplane fluoroscopy, the relative contributions of the acetabular labrum and the ILFL in maintaining hip joint stability, as measured by ER, IR and anterior translation of the femur relative to the centre of the acetabulum, concluding that the ILFL had a significant role in limiting ER and anterior translation of the femur, while the acetabular labrum provided a secondary stabilizing role for these motions.[23] Bakshi et al also recently evaluated anterior hip stability in capsular sectioned states with a labral injury on 16 hips specimens, finding that the ILFL is crucial in preventing anterior translation in labral-injured states.[24]

Kivlan et al, using a string model, described and compared the length changes of the ILFL in the test positions commonly used to assess hip ligament laxity, in order to evaluate the microinstability of the hip, finding that, for the MILFL, the greatest change occurred in the adduction-extension-ER position, while for the LILFL the greatest excursion resulted in the adduction-extension-ER position (16.6 mm).[15]

Recently Burkhart et al characterized the ligament strain in the hip capsule using a novel computed tomography (CT) based imaging technique.[25] Strains were calculated by comparing bead separation in loaded and unloaded conditions. For the SBILFL, strain significantly decreased in IR at 30° and 60° versus 0°. For ER, there were no significant position-specific changes in strain. For the IBILFL, strain decreased in IR and increased in ER with no significant position-specific differences.[25]

Role of the ILFL during surgery

Iatrogenic injuries

One difficulty for the new hip arthroscopist is visualizing all areas of the hip and then having adequate access to treat them without damaging adjacent structures. For adequate access to the hip joint, it is recommended that the capsulotomy should be made 5–10 mm distal and parallel to the labrum to allow for adequate capsular closure.[26] During hip capsulotomy, preservation or repair of the ILFL is critical, especially in patients with hip dysplasia and joint laxity.[26]

Fagotti et al quantified the damage to the soft tissue stabilizers of the hip after a transverse interportal capsulotomy and subspine trimming in a hip arthroscopy.[26] The width of the proximal capsule was measured before and after subspine trimming. The extent of damage to the ILFL after dissection was recorded. Potential damage to pericapsular structures was assessed by measuring the distance between the capsulotomy and rectus femoris and iliocapsularis muscle with an electronic calliper. In all specimens, the authors found that more than 50% of the ILFL was damaged, confirming the potential damage to the native capsule and pericapsular structures when using a transverse interportal capsulotomy.[26]

Wylie et al found that out of 1,100 patients who underwent hip arthroscopy, 33 presented with postoperative instability requiring surgical repair, and recently, Gehrman et al and Mei-Dan et al reported cases of iatrogenic instability after a hip arthroscopy which required hip arthroplasty and open capsular reconstruction in the two patients, respectively.[27–29]

How to repair an injured ILFL

In case of an ILFL injury, several techniques have been described to repair it, both using and not using an allograft. In case of an iatrogenic lesion during total hip arthroplasty, using a posterolateral approach, Liu et al described a simple, rational technique for reinforcing the SBILFL.[30] A meticulous exposure of the hip capsule is performed during the posterolateral surgical approach, after which a trapezoidal capsulotomy is performed. After the insertion of the arthroplasty implants, retractors are placed to expose the superior capsule. Prior to the transosseous repair of the capsule and short external rotator tendons, the proximal limb of the capsulotomy is reapproximated anatomically and repaired with non-absorbable sutures.[30]

Fujishiro et al reported the reconstruction of the iliofemoral ligament using a Leeds-Keio artificial ligament to prevent anterior dislocation in a patient who underwent four hip arthroplasty revision surgeries.[31] A double-bundle Leeds-Keio ligament was secured to the AIIS and the anterior acetabulum using a screw and two staples. The Dall-Miles cable was then passed around the proximal

prosthesis through which the ligament was passed, and its far end was attached to the prosthesis.[31]

Gehrman et al described the use of an Achilles tendon allograft for an open anterior hip capsuloligamentous reconstruction in a female athlete with post-arthroscopic hip pain and capsular laxity.[11] Similarly, Yeung et al described a novel technique of management through anterior hip capsuloligamentous reconstruction with Achilles tendon allograft, which varied differently from Gehrman in that it used a trapezoidal graft. In this case, the Achilles allograft was prepared and fashioned into a Y-shaped configuration to mimic the native iliofemoral ligament.[32]

Discussion

The main findings of our study were: (1) the ILFL is the largest of the hip joint capsular ligaments and consists of two distinct arms, which share a common proximal origin and, moreover, the ILFL has high variability, both in its location and overall size, when compared to the ISFL and PFL; (2) the most sensitive and specific method for studying the ILFL was MRI, although no radiological classification on ILFL lesions was described; (3) in the case of hip dislocations, the ILFL tear did not heal, resulting in a persistent anterior capsule defect; (4) clinically, the ILFL is felt to limit ER in flexion and both IR and ER in extension, and that the AB-HEER test is overall the most accurate test to detect ILFL lesions; and (5) the ILFL played a primary role in anterior hip stability and the resection of the ILFL and could increase the load on the labrum through impingement in extension or abduction, which may be perceived as pain and possible subluxation.

The anatomical considerations of the present study highlight that the key role of the transverse and descending parts of the ILFL were the joint capsules, with fibres arranged according to the connection with the gluteus minimus tendon and the deep aponeurosis of the iliopsoas, respectively. So far, the ILFL is not only a static stabilizer but also acts as a dynamic stabilizer, transmitting muscular power to the joint through the capsular complex.[33] Tsutsumi et al confirmed that the ILFL might be able to maintain its tension through the contraction force of the gluteus minimus and iliopsoas to some extent, even in hip positions in which the ligament is often considered to be becoming loose.[33]

The importance of the ILFL has also been shown in a case report published in 2003, which demonstrated how ILFL reconstruction restored stability to a hip that previously experienced recurrent anterior dislocation.[31] A similar and more recent study demonstrated that ILFL repair allows maintenance of normal hip translation and rotation following ILFL transection or injury.[23]

The advances in arthroscopic hip surgery in the last few years have focussed more on pathologies that were least considered before, in particular, capsular lesions and traumatic and non-traumatic instability.[34,35] Further, iatrogenic lesions of the iliofemoral ligament are not uncommon during arthroscopic procedures, especially during capsulotomy. In fact, capsulotomies are required for hip arthroscopy to visualize and treat the underlying hip pathology. Although the size, type and location may vary according to the surgeon's preference, capsulotomies typically cut into the ILFL, in a Y-shaped cut near its acetabular origin.[36] The ILFL being reported to be a primary stabilizer in external iatrogenic damage can lead to postoperative complications, such as hip instability or dislocation. The literature reports several cases in which instability after hip arthroscopy was attributed to violation of the anterior capsule and the ILFL. The subsequent instability in all cases was resolved by the repair of the anterior capsule, suggesting an important stabilizing function of this ligament.[28,32] Another important feature of the ILFL is its microscopic composition, as when compared to the distinct characteristics of the LT and the ACL, the IL is a less specialized ligament, showing a lower level of collagen types I, III and IV, confirming its main role as a static stabilizer.[12] Similar results were confirmed by Sato et al, highlighting that the contents of elastic fibres are very rare in the ILFL, suggesting that the elastic fibre content does not relate to the functional significance of the ligament in the hip joint.[11]

Our review also analysed the imaging of the ILFL, noting that currently, the gold standard for identification and visualization is the MRI; in particular, the IBILFL is best visualized transversely in the axial and axial-oblique planes and longitudinally in the sagittal plane while the coronal and axial-oblique planes yielded good views of the SBILFL.[13,37] Further, MRI was able to detect an ILFL rupture after a traumatic hip dislocation and as part of a characteristic triad of MR findings.[38] Jia et al demonstrated that after hip dislocation, the ILFL does not heal, thus leading to a possible situation of hip microinstability.[14]

Furthermore, we analysed the biomechanics of the ILFL present in the current literature, which confirms the importance of this ligament for hip stability in different positions. Bakshi et al confirmed that the ILFL plays a primary role in anterior hip stability in the labral-injured state, providing a restraint to anterior translation when the stabilizing effect of the labrum has been lost.[24] These findings are confirmed by Myers et al, demonstrating that the repair of both the iliofemoral ligament and the labrum significantly decreased translation and external rotation, as compared to a labral repair alone.[23] The results of the study would indicate that the ILFL is vital to limit excessive amounts of ER and anterior translation of the femur. Supporting this theory, recent

clinical studies reporting on capsular plication to treat ILFL deficiency have shown improved patient outcomes with the restoration of anterior support.[39]

Van Arkel et al, analysing the role of soft tissues in hip instability, did not find an increase in the risk of dislocation after the resection of the ILFL, but found the loss of primary external rotational restraint across the complete range of motion (ROM) could increase the load on the labrum through impingement in extension or abduction, which may be perceived as pain and possible subluxation.[19] This suggested that capsular ligaments repaired during early intervention surgery reduced the risk of hip subluxation and labral overloading. This is particularly relevant in dysplastic hips with a high risk of developing hip instability.[40]

In 2018, van Arkel et al analysed how total hip arthroplasty (THA) affects the early postoperative function of hip ligaments, revealing that THA inherently reduced the ability of native anatomy capsular ligaments to restrain hip motions. This was because in the native hip, capsular ligaments pull taut by wrapping tightly around the surface of the native head, whereas following THA, the smaller postoperative femoral head does not have this tensioning mechanism. The anterior capsule was less affected, particularly in flexion, because it had less of a dependence on wrapping. With its straight line of action, the lateral arm of the iliofemoral ligament, the primary restraint to external rotation, was largely unaffected by the THA procedure to the extent that lengthening the neck too far restricted external rotation. This means that, in the early postoperative period, the native anterior capsule anatomy may remain functional in constraining range of motion, but the native posterior capsule anatomy will not.[40]

Interesting findings were reported by Hidaka et al, suggesting that long-term physical therapy can be safe and effective in treating hip contracture.[21] In particular, a selective stretching procedure for the ILFL should be always considered. Selective separate stretching should be applied for the IBILFL and the SBILFL, in order to reduce total stress on the contracted ligaments of the hip joint, thus reducing the risk of chronic inflammation generated by microrupture due to excessive strain.[21]

Finally, Schleifenbaum et al, contrary to what is assumed, showed no evidence of a linear change in the ILFL with ageing, leaving many doubts about the underlying mechanisms related to the loss of elasticity in the hip joint ligaments unaddressed.[17]

Future studies will have to analyse and develop clinical tests to evaluate both isolated and associated ILFL lesions. In clinical practice, however, several studies are already evaluating the short- to medium-term results of capsuloplasty and the associated ILFL reconstructions, with excellent results, confirming how this ligament should always be taken into consideration in hip instability.

Conclusions

In conclusion, this review confirms that the ILFL is the largest hip ligament, consisting of two distinct arms and with high variability, both in its location and overall size. Injuries of the ILFL could be iatrogenic or as a consequence of traumatic hip instability and can be successfully studied with MRI. Finally, the ILFL plays a primary role in anterior hip stability, and future studies will have to develop clinical tests to evaluate its functionality and stability. Moreover, new biomechanical and clinical studies will help clarify the clinical relevance of this ligamentous structure in hip capsule injuries and instability.

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PERMISSIONS

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